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ANNA SPIESMAN STARR

A THESIS

IN PSYCHOLOGY

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
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Reprinted from THE PSYCHOLOGICAL CLINIC, Vol. XV, Nos. 3–4, 1923.
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THE DIAGNOSTIC VALUE OF THE AUDITO-VOCAL DIGIT MEMORY SPAN.

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The audito-digit memory span is one of the oldest psychological tests, having been devised by Jacobs (1) in 1887. He found that the length of the span tended to increase with the age of the individual. Beginning in 1885, Ebbinghaus (2) carried on an experimental investigation of memory, using nonsense syllables as the material. In these first experiments he was both subject and experimenter. He had faith in the possibility of maintaining the constancy of conditions requisite for investigation of the higher thought processes, and to express the results numerically. Subsequently, he worked with children, and his findings indicate that the number of digits an individual can correctly recall increases with age. Smedley (3) reported in 1889 that among school children, memory span norms were "conditioned by age" in each of his several modes of presentation. In the original Binet-Simon series (4) this test is found, and although the age norms have been shifted, it is still retained in all the revisions. There have been other more recent investigators both in this country and in Europe. Whether the studies were with large or small groups, the findings have in general been similar, although in many cases the results are not directly comparable because of differences either in the method of presentation or in the manner of scoring. Humpstone (5) in 1917 examined a number of children in school class groups and found the usual increase of span with increase of age. He established the norm for first grade proficiency, holding that "above five or six years, or the first grade, one should have a span of five or more." His investigation, as in the case of most of the others, was carried out by the group method which necessitated the immediate written reproduction of a series of digits presented in an even tone and tempo. The Binet-Simon series, however, required

individual examinations and from the ninth year level in the Stanford revision, preference is given to repeating the series backward. This method had been suggested by Bobertag (6) in 1911, but the Stanford investigation (7) seems to have been the first attempt toward its regular use and standardization.

The present investigation was carried on in the Neuro-psychiatric Division of the Municipal Court of Philadelphia, from January, 1921, to January, 1923, at the suggestion of Professors Lightner Witmer and Edwin B. Twitmyer, of the University of Pennsylvania. The results here presented are compiled from individual examinations of 2000 white dependent children between four and fifteen years of age, inclusive, whose families applied for social adjustment or financial aid at the Court. This investigation was undertaken:

1st. To determine the audito-vocal-digit memory span characteristic of the age and competency levels of school children, through individual examination, employing for the purpose the Forward, Reverse, and Rhythmic methods of presentation.

2d. To formulate the value of the audito-digit-vocal memory span as a diagnostic measure in individual examinations.

3d. To study the quantitative results with a view to their interpretation in terms of the mental processes involved.

Cases of insanity and of idiocy were barred from the study, as were those suffering from any neural disturbance at all serious. This was readily accomplished, as each child received a thorough physical, neurological, psychiatric and psychological examination before a judicial decision was made, and all of these findings were available to the investigator. Most of the children had been brought to Court for more or less temporary placement, due to parental neglect, separation, unemployment or parental disability through sickness or death. Otherwise the children were unselected and correspond to the rank and file of school children in a community of medium economic and social stability. As this group contained children at various levels of mental development, their examination may be expected to produce standard measures and to indicate the range of the Normal, Retarded, Subnormal and Low Grade Defective children at each age level. An opportunity is here afforded to discover whether or not a given memory span considered adequate for age in a Normal case is ever found in a Defective case of the same age.

Definition of Terms.

The *Forward Memory Span* is the maximum number of digits which can be repeated verbatim upon a single presentation of a given series.

The *Reverse Memory Span* is the maximum number of digits repeated in reverse order, upon a single presentation of a given series.

The *Rhythmic Span* is a forward span in whose presentation the digits are given at such a tempo and with such emphasis that they naturally fall into definite groups. For this study, groups of three were used.

By a *Normal* child is meant the child who gives adequate evidence that his mental development is at least equal to the social norm for his age.

By a *Retarded* child is meant the deficient child who fails to reach the standard of his age, because of environmental conditions rather than of competency defect.

The *Subnormal* group is the group of defective children corresponding to the Middle Grade Imbecile of the Barr (9) classification and the Moron as defined by Goddard (10).

The *Low Grade Defective* includes such children as the Low Grade Imbecile and Idio-Imbecile (Barr).

Method.

The Memory Span test was given in each case as a regular part of a complete psychological examination. Upon entering the Clinic, the child was presented with the material for the different Form Board performances, and the Witmer Cylinders. In those cases where timidity or fear appeared as a factor, the test was not given until the child seemed entirely at ease. After a good *rapport* had been established, the child was urged to "say these numbers just as I say them", whereupon a series of three digits were given. When the response was correct another series increased by one digit followed, and this procedure was repeated until the child failed to recall correctly. The highest number of digits correctly reproduced upon a single presentation was held to be the memory span. Two correct responses in four trials were required, in order to eliminate the possibility of chance. In the series used, no digit followed another in either their natural or reverse sequence and all familiar grouping such as historical dates was avoided. Furthermore, the new series neither began nor ended with the first or last digit of the preceding series; no digit was repeated in the same series and zero was never used. The digits were pronounced clearly, without rhythm (except in the Rhythmic Span) or emphasis and at an even tone and tempo (three digits in two seconds). With the last digit the tone of the voice was lowered, indicating the end of that series.

After the Forward Span had been determined, the grouped or Rhythmic Span was given. Here three digits were grouped together

with slight acceleration in time, but the tone and time of each group remained constant. The children enjoyed this method particularly, because they felt a sense of accomplishment in their ability to give a longer span.

Following some little praise for the child's efforts, the examiner said, "Now I want you to say these numbers a different way. Do not say them as I do, but say them backwards. If I say, seven, one, you say one, seven. Do you understand? What will you say if I say four, nine?" After a correct response. "And six, two? Right." "Now, say this one backwards. Three, one, eight." Then followed a series conforming to the procedure of the Forward Span. The highest number of digits correctly reversed determined the Reverse Span. Here again, two correct responses out of four trials were required.

The psychological examination was then duly continued, various clinical tests and measurements being employed, including the Stanford Revision of the Binet-Simon Tests.

TABLE I.

Age.	Normal.		Retarded.		Subnormal.		Low Defective.	
	Forward.	Reverse.	Forward.	Reverse.	Forward.	Reverse.	Forward.	Reverse.
4	4	F	3 & 4	F	3	F	3	F
5	4	F	4	F	4	F	3	F
6	5	F	4	F	4	F	3	F
7	5	III	4	F	4	F	3	F
8	5	III	5	III	4	F	3	F
9	5 & 6	IV	5	III	4 & 5	III	3 & 4	F
10	6	IV	5	III	5	III	4	F
11	6	IV & V	5 & 6	IV	5	III	4 & 5	F
12	6	V	6	IV	5	III	4 & 5	III
13	6 & 7	V	6	IV & V	5 & 6	III & IV	4 & 5	III
14	6 & 7	V	6 & 7	IV & V	5 & 6	IV	4 & 5	III
15	7	V	6	IV & V	5 & 6	IV	4 & 5	III

RESULTS.

In Table I, the *mode* distribution of the Forward Memory Span for chronological age and mental development is given in Arabic numerals. The modes are definite throughout and where the distribution is bi-modal, that condition is also indisputably clear. The results of boys and girls are grouped together, since no sex difference appears in their separate compilation. This has been the common observation in many of the larger studies of the memory span, *i. e.*,

there is no appreciable sex difference. The results of the Forward Span cover 2000 cases, of the Reverse Span 1450 cases, the present study being the most extensive yet reported of the audito-vocal-digit memory span of children through *individual* examinations. In the table the mode distribution of the Reverse Span is indicated by the Roman numerals. F indicates that the child failed to demonstrate a Reverse Span of three digits, either through lack of comprehension or being able to reverse only two digits. The table clearly indicates how dependent the length of either span is upon both age and mental development. In each instance it varies with the *ratio* between them.

The Forward Span.—From the distribution, it is evident that—

(1) The Forward Memory Span increases with an increase of age and competency.

(2) The increase in the Forward Span occurs in steps. In the Normal group, the years six through eight, nine through eleven and twelve to fifteen inclusive represent definite levels of attainment.

(3) The lower Forward Memory Span has more value as a diagnostic criterion, because in the distribution for age and diagnosis there is much overlapping at the middle and upper end. This indicates that, as a test, the Forward Memory Span does not adequately differentiate among the older and more competent groups.

The Reverse Span.—The results of the Reverse Span show that—

(1) The length of the Reverse Span is shorter than the Forward Span.

(2) The ability to increase the Reverse Span is a more gradual development than the ability to increase the Forward Span.

(3) The Normal child does not comprehend it until he is about seven years old and has a Forward Memory Span of at least five digits.

(4) The Normal child of twelve years and above reverses five digits readily, but very seldom six digits.

(5) A Subnormal child of twelve years is able to reverse four and very frequently only three digits, even though his Forward Span may be six or six plus.

(6) The Low Grade Defective can not demonstrate the Reverse Span above three digits; usually he does not comprehend it at all, no matter what his Forward Span may be.

(7) Increase in the length of the Reverse Span also occurs in steps. In the Normal group the divisions coincide with those made by the Forward Span. This would indicate that such age groups are in fact homogeneous.

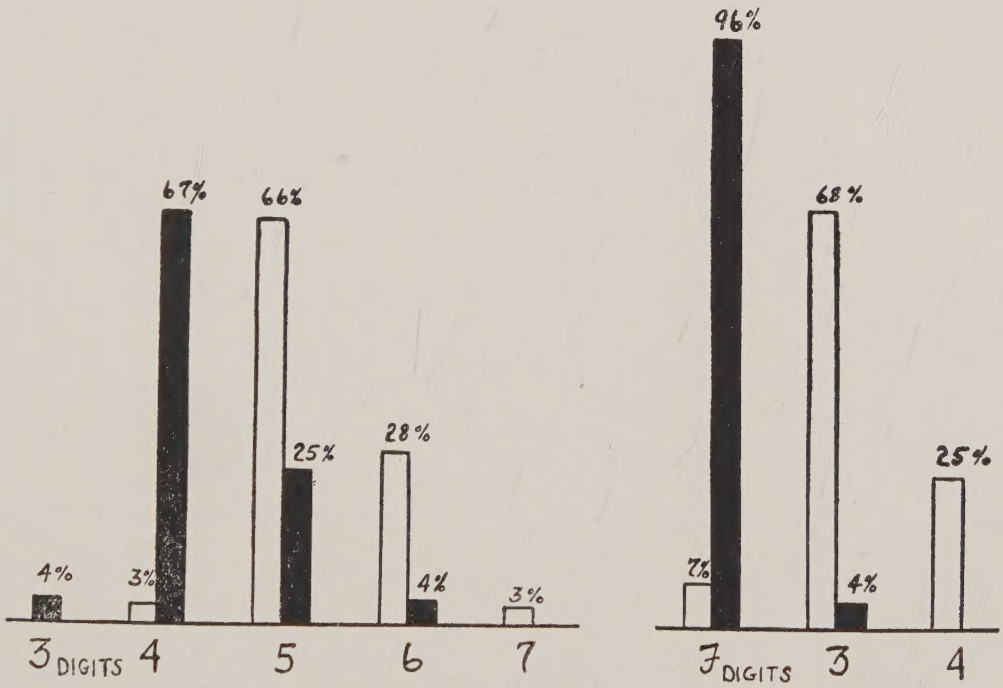

CHART 1–A

CHART 1–B

Relative Frequency of Normal and Subnormal 7 and 8 year old Children, giving a Forward and Reverse Memory Span as indicated.
(Solid Portion in all charts indicates Subnormal Group.)

(8) In the Normal cases, there is evident a constant relation between the Forward and the Reverse Memory Span, which may be expressed as X and (X-1) or (X-2).

(9) It is evident that the Reverse Memory Span is superior to the Forward Span, as a diagnostic measure of finer discrimination, because the groups formed thereby tend to be much more mutually exclusive than those formed by the Forward span.

They clearly indicate how dependent the length of either span is upon both age and mental development. In each instance it varies with the *ratio* between them.

Taking each of the three age groups into which children seem to be divided by the memory span test—those seven and eight years old, those nine to eleven and those twelve to fifteen years old—and considering each group separately in relation to his competency, the real diagnostic value of the memory span becomes clearly evident. The Normal and Subnormal groups are here contrasted, because it is between these two closely related groups that the Clinician is most often called upon to differentiate. Between the Normal and the Low-grade Defective the difference is naturally very much greater.

Chart 1-A shows the distribution in relative frequency of the Forward Memory Span for both Normal and Subnormal groups of seven: and eight years of age; Chart 1-B shows a similar distribution for the Reverse Span. The modes in the Forward Spans are definitely placed—the Normal being five digits, the Subnormal four. The charts indicate also the range of distribution for both groups at the same age level and show that the Subnormal group as a whole, including its upper and lower limits, consistently corresponds to that of the Normal group, but is one digit shorter. With the Reverse Span, the cleavage between the groups is even more pronounced. Of the Subnormals, 96 per cent of the seven and eight year old children fail to reverse three digits, while only 7 per cent of the Normals fail so to do; 93 per cent of the Normals reverse three or four digits in contrast to the 4 per cent of the Subnormals, who can reverse only three digits.

Chart 2-A shows a similar treatment of the results of the Normal and Subnormal groups of nine to eleven years. In the case of the Forward Span, the distribution tends to be bi-modal. The spread of the Subnormal group covers a range that is consistently one less than that of the Normal group. The Reverse Span (Chart 2-B) shows a very much sharper discrimination between the group at this age level and establishes a decided mode for each—four for the Normals and three for the Subnormals.

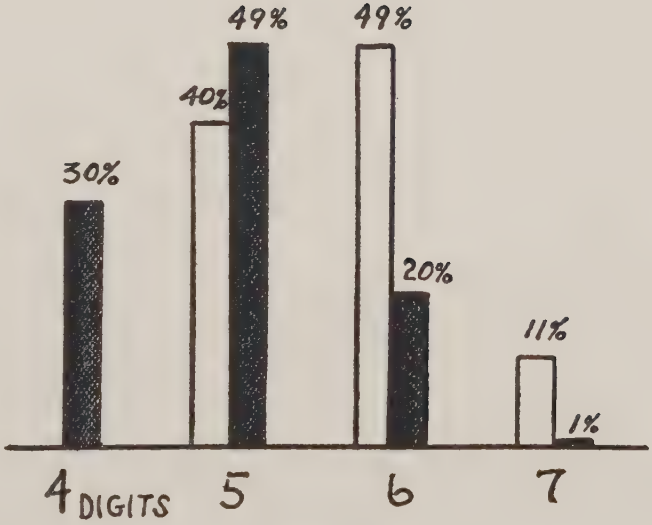

CHART 2–A

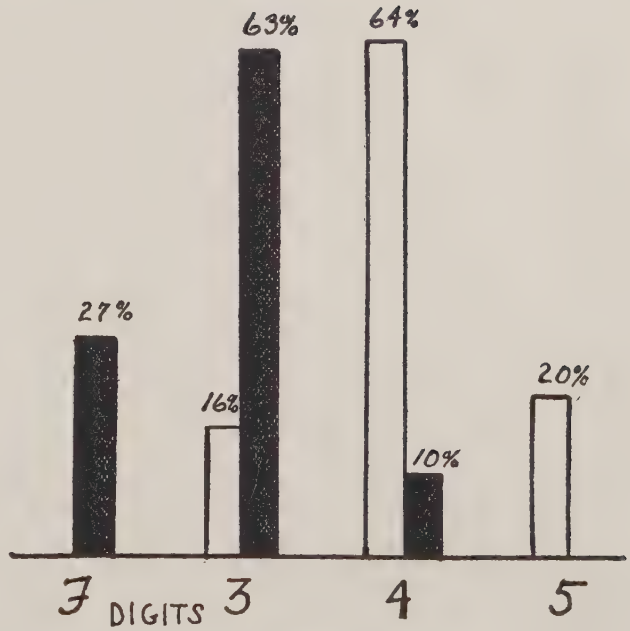

CHART 2–B

Relative Frequency of Normal and Subnormal 9, 10, and 11 year old Children, giving a Forward and a Reverse Memory Span as indicated.

Chart 3-A considers the adolescent level (twelve to fifteen years) and shows the characteristically wider spread for both groups in the Forward Span, indicating it to be of much diagnostic value only at its lower end. With the Reverse Span (Chart 3-B), the mode for the Normal group is definite and above the bi-modal distribution of the Subnormal group.

At each of the three levels the superiority of the Reverse Span has been plainly demonstrated, both in (1) its more definite establishment of age modes and (2) in the sharpness of the group differentiation.

The Rhythmic Memory Span.

The length of the Rhythmic Span tends to maintain a constant relation to the Forward Span at all ages and with all groups. This relationship may be expressed by the formula X + 1, X being *any* specific Forward Span at *any* age in *any* competency group. Of 1400 cases, 72 per cent conformed to the formula X + 1, 13.8 per cent to X + 2, only 0.2 per cent to X + 3, and 14 per cent showed no variation from the Forward Span. It is possible that the cases whose Rhythmic Span increases as much as two digits over the Forward Span are in a transition state. They may be developing the ability to increase their Forward or Reverse Span, and the evolving ability can express itself earlier in the Rhythmic Span because it is easier. It is also possible that in such cases the child's associability may be functioning particularly well and that the number of the groups of digits corresponds to a Forward Span of greater complexity. Applying this idea to the group whose Rhythmic Span shows no increase over the Forward Span, it would suggest that the prognosis for these cases may be unfavorable, *i. e.*, that they had approximated their level, or at least were at a standstill. The investigator is of this opinion, because in practically all such cases the Reverse Span was also deficient.

The results of the Forward and Reverse Memory Span establish that the length of the span increases concomitantly with age and competency, being dependent upon *both*. Considering this in relation to the Rhythmic Span, the findings obtained by the use of the latter become highly significant. They bring further evidence that that which functions in response to the Memory Span Test is a definite complexus of competencies, so closely synthesized that (1) its response varies only within prescribed limitations as the method of presentation varies, and (2) its functioning efficiency is dependent upon the maintenance of a definite inter-relation between the Forward, Rhythmic, and Reverse Spans. It further suggests that the

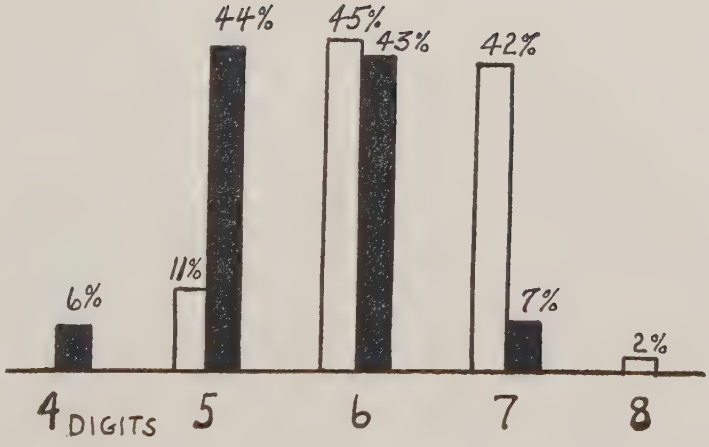

CHART 3–A

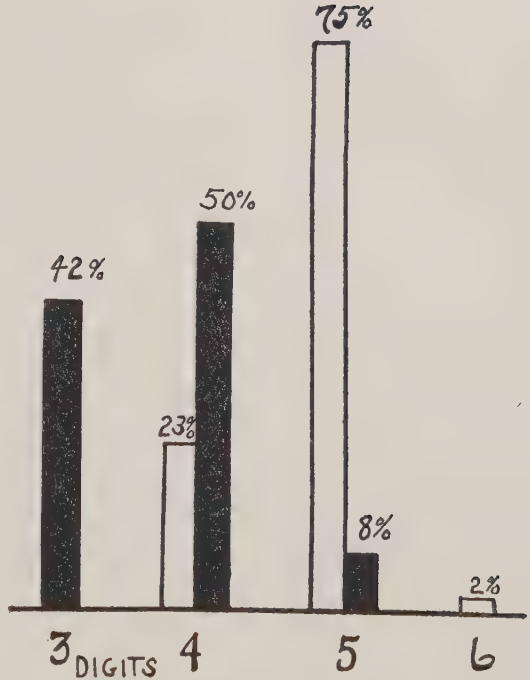

CHART 3–B

Relative Frequency of Normal and Subnormal 12, 13, 14 and 15 year old Children, giving a Forward and a Reverse Memory Span as indicated.

overlapping noted in the charts may be due to the presence or absence of certain phases of the complexus compensating for the deficiency of the whole.

Discussion.

The response to any stimulation depends primarily upon congenital endowment. One must have the structural equipment to receive the sensation, to register it, and to give the natural response. Not only must the sensory-motor mechanism be present, but it must also function in a coördinated manner in answer to stimulation. The moment at which a single mental ability functions alone is a theoretical moment, for any response above the simplest reflex involves many factors. It is very probable that at such a time as the infant is, for the first, cortically aware of a specific sensation, his mental life has already become complex. Genetic psychology traces step by step the evolution of the individual's mental make-up, from the hypothetical first and pure sensation to the highest functions of judgment and creative thought. Sensitivity as a congenital ability depends primarily upon the protoplasmic properties, irritability and subsequent modifiability. Sensation raised to a higher level becomes ideation. Associated sensations and ideation form our mental content and when recalled are memorial elements. Memory enters into the formation of concepts and the higher thought processes. Sensation, ideation, association, memory, judgment, each one is possible because of the efficiency of those less complex processes upon which it is built. Its own efficiency is directly proportional to theirs. Each act is thus a complexus (in truth but a functioning formula) to a large extent differing from each other act in emphasis upon component parts.

Jacobs called his first studies with series of digits "Experiments in Prehension." He sought to measure an ability. Whipple (7), who has compiled a most complete bibliography on this test, maintains in his discussion that the capacity tested corresponds to what the Germans call "*Merkhäfigkeit*" and suggests "immediate memory" as an adequate translation. Indeed, so many investigators have maintained that the immediate reproduction of a series of perceptions measures memory, that the test has been called the "memory span". This is scarcely to be taken literally, for retentivity over a longer period of time is not adequately measured by immediate response. On the other hand, the time element in immediate reproduction, being at such a minimum, has suggested that recalling the digits approximated a description of an after-image.

As investigators have found that the visual memory span is generally longer than the auditory span of the same individual, it is evident that imagery plays an important part. Certainly there is close co-functioning between the different types of imagery. This interplay is particularly obvious in the case of many children who stare into space as they hear the number given, and who are but visually placing each digit in sequence, thus vicariously reinforcing their auditory stimulus. Such children give longer spans, for they successfully synthesize the functioning of the different fields of imagery. The very synthesis itself is but another indication of their level of cerebration.

In *l'Intelligence des Imbeciles* (*L'Année Psychologique*, 1909, pp. 1–47), Binet evaluates the memory span for digits as a test to measure the individual's capacity for effort. He notes that "a normal subject according to the pains he takes can repeat from six to nine figures or even more"; that the defectives are able to repeat fewer numbers than the normal cases, and he concludes therefrom that all results show "the incapacity for effort which exists among defectives."

Smedley (3) reports that the "audio-visual-articulatory memory is stronger than the audio-visual". For him the memory span measures congenital "memory power". It shows "what a child can apprehend—not what he can comprehend". Humpstone (5) too is very decided in his analysis. He insists that although memory, intelligence, attention and imagination are involved in the test, "the thing that is specifically tested is the ability to grasp and associate a number of discrete units of perception in a definite order . . . that so far as it is possible to single out one ability, it is associability that is tested by this test. . . . Perhaps the memory test comes nearer to testing one definite ability than any other test."

The interpretations given in in the foregoing resumé have all been concerned with the Forward Span. Among them there is little agreement. For while some investigators claim it to be a measure for a specific ability, there is a difference of opinion as to what that ability is. Others have agreed that it is a complexus, but disagree as to the components thereof and upon which the greater emphasis is placed. However, the fact that the Memory Span Test has been the subject of so many investigations over such a long period of time, testifies to the possibilities psychologists have held it to have as a diagnostic measure.

To interpret the results of the present investigation it is necessary to consider separately those obtained as the Forward, the Rhythmic and the Reverse Span. The results of the Forward Span

show an increase in the length of span concomitant with age and mental development, as do also the results of the Reverse and Rhythmic Spans. Furthermore, in the Normal group there is a definite relation between them which tends to be expressed as X, X − 1 or X − 2, and X + 1. This suggests that while the same competencies may be the only ones involved in each of these three methods of presentation, the *constant variation* in the length of the spans indicates that the demands made by each of them must somehow differ. If such is the case, a defect or deficiency in any one of the component mental processes will appear more definitely in the span whose response involves that particular competency the most. It will also mean that the increase in the length of any span of four to seven digits is evidently due to the higher development of the competencies of the four-digit span and consequently can be expressed at a higher plane as a seven-digit span. Furthermore, it follows that the difference in the length of the Forward Span, of the Rhythmic Span and of the Reverse Span of the same individual is due to the proportional variance within the complexus itself, which is called upon to function in the required response.

For example: a child may have deficient retentivity, good attention and fair imageability. He will probably give a Forward Span adequate for the Normal child of his age, but will in all probability fall short in the Reverse Span, not only because his retentivity is inadequate, but also because his imageability, being barely above the line of sufficiency, is not able in its response to arouse an image intense enough of itself to endure. A good imageability in conjunction with adequate attention would, in part at least, compensate for the lack of retentivity.

Again, a Normal child of nine years may have a fully adequate development for a Forward Span of six digits but his Reverse Span is only four. This means that the cerebral organization necessary for the Reverse Span of an equal length is beyond the Normal nine-year level, *i. e.*, the Reverse Span makes a greater demand than does the Forward Span of equal length.

Realizing that a working analysis of the Memory Span can indicate only the more general competencies involved, the following is tentatively suggested as being the minimum requirement. Granting that the subject is structurally able both to perceive the digits and to reproduce the series, it appears that the congenital abilities involved are, for the normal case, as indicated in Table II.

Perhaps introspection can tell us just what does enter into the response of each of the spans, but the introspectionists are not as yet prepared to formulate accurately the degree to which any competency

TABLE II.—FOR THE NORMAL SPAN.

1. In the Forward Span of (X) digits.	2. In the Reverse Span of (X-1) or (X-2) digits.
Attention.	*Attention.*
Extension:—Wide distribution.	Extension:—Narrower distribution.
Intensity:—Adequate just to perceive (X) digits.	Intensity:—Greater, to retain digits longer in focal point.
Comprehension.	*Comprehension.*
Not necessarily above the two-year level, as process is merely imitative.	At least the six-year level. (Shown by results of this investigation.) Process involves reorganization of perceptions.
Imageability.	*Imageability.*
Extension:—Adequate for span of (X) digits.	Extension:—Adequate for span of (X-1) or (X-2) digits.
Intensity:—Adequate for span of (X) digits.	Intensity:—Greater, to ensure the independent unity of each digit.
Associability.	*Associability.*
Adequate for span of (X) digits, of simple order-sequence type.	Adequate for grasping sequence of span of (X-1) or (X-2) digits, but not so great as to impede reversal.
Retentivity.	*Retentivity.*
Minimum.	Of greater duration.
Recall.	*Recall.*

is involved. The memory span performance is too complicated. Nor is such a fine discrimination of the competencies necessary to be known, for individual compensations are always being made and it is the resulting proficiency in their co-relation that is of importance in making adjustments. It is upon their co-functioning that the individual's performance depends. It is unwarranted to assume even in the case of Normal children, that their equally successful responses are due to competencies, quantitatively or qualitatively identical. One child may have a keen visual imagery and as he hears the digits, he quickly transfers them to the visual field. Another equally competent child combines the auditory and kinesthetic imagery, while yet a third depends upon his audition. One child may need to force his attention, another attends without effort because his imagery and retentivity are more easily excited.

In this very freedom for the child to use any or all of his competencies, lies the value of the test, for it calls into natural play the individual's congenital equipment—the same equipment he uses in making the adjustments of his everyday life. The findings of this

investigation point conclusively to the proposition that the Memory Span indicates the ratio of proficiency in the co-functioning of the competencies involved, rather than the specific degree of development of each or all. It is rather an estimate of how well these competencies work together than to what extent each or all are present.

The Forward, the Rhythmic, or the Reverse Spans considered separately do not afford sufficient range for the observation of the functioning competencies. Taken together, they form a more adequate basis for diagnosis. If we agree that concentration and retentivity are necessary in the Forward Span, then certainly it is clear that they are necessary to a greater degree in the Reverse Span. If immediate verbatim recall is reproductive imagery, then the Reverse Span is productive imagery, *i. e.*, the reassembling of former perceptions in an entirely new order. Being a more complex process, the latter functions only at higher levels. The Reverse Span is the more difficult because it requires the more highly evolved organization and the results of this study show that it indicates a definite level of mentality quite apart from that indicated by the Forward Span of the same individual.

In the light of this interpretation, that the Memory Span indicates the ratio of proficiency in the co-functioning of the competencies involved, let us reconsider the charts. Does such an interpretation explain the individual deviations from the group norm, as well as the overlapping of the groups themselves? Does it suggest the reason why the adolescent Moron usually reverses four digits and also, why there is the occasional five digit reverse span in that group, in apparent contradiction to so general a rule?

The individual deviations from the group norm of seven and eight year old Normal and Subnormal children are shown in Chart 1-A and B. Of the Normal children, 66 per cent had a Forward Span of five digits, 28 per cent had a span of six digits, 3 per cent gave seven and 3 per cent gave a span of four, *i. e.*, 97 per cent of Normal seven and eight year old children had a Forward Memory Span of five or more digits. Accepting the group norm to be established as five digits, we find 31 per cent of the cases functioning at a higher level. In this group are those children who have already attained the proficiency of the next older group along any line whose performance requires the functioning of such competencies as are involved in the Forward Span. The cases represented by the 3 per cent of Normal children having a Forward Span of four, were diagnosed as Normal, dull. The Reverse Span was three, the Rhythmic five. In each case their reaction time was slow throughout the entire performance. There would seem to be some inadequacy of distribution of

attention with partial compensation by concentration of attention sufficient to maintain normality at that early age level.

In the Subnormal group, 67 per cent of the cases responded with a Forward Span of four digits; 29 per cent had a five or six digit span, and 4 per cent were able to repeat only three digits. The norm for seven and eight year old Subnormal children is thus established as four digits for the Forward Span. Why should there be these 29 per cent of Subnormal cases who are able to give a Forward Span at least equal to the norm established by recognized Normal cases of the same age? The findings show that of the 29 per cent, no child was able to reverse 3 digits. Obviously then, the explanation is, that while their competencies functioned well enough to respond adequately for the Forward Span, there was present in these cases an innate defect or deficiency in those competencies upon which the Reverse Span depends, but which are not essential to the same degree in the Forward Span; also, that this deficiency was great enough to interfere with the child's general performance level to the extent that he was recognized as definitely subnormal. The possible combinations of such a condition are numerous. A child may have good distribution of attention and imageability but lack comprehension sufficient to understand that the Reverse Span means that all digits are to be given in exactly reverse order, not just slightly disarranged. A common error has been to begin the response with the last digit heard and then proceed to recall the series as a Forward Span. The degree of comprehension necessary to reverse three digits appears to be an adequate measure of comprehension required of the seven and eight year level, for in Chart 1-B, it is shown that 93 per cent of the Normal children reverse three or four digits, while 96 per cent of the Subnormal children fail to do so. There remain the 7 per cent of Normal children who failed to reverse three digits and the 4 per cent of Subnormal children who did reverse three digits.

In the case of these Normal children failing to reverse three digits, each gave a Forward Span of five digits and a Rhythmic Span of 6. It is somewhat difficult to explain wherein these children differ from the "29 per cent group of Subnormal" children who also had a Reverse Span of below three, a Forward Span of five and a Rhythmic Span of six. There are, however, three possible explanations of this condition.

(1) Either these Normal children were just above the lower limit of normality and their deficiency will become progressively more apparent with increase of age, while in the case of the Sub-

normal children, their deficiency has already become evident. (A quantitative, rather than a qualitative, difference.)

(2) Or, the *actual* memory span was not obtained in the case of the Normal children, *i. e.*, the memory span operative at that time was not the child's true span.

(3) Or, some other factor or factors, such as character defects or psychoneurotic tendencies, conflicted with the normal functioning of an otherwise adequate mentality.

The cases D. C. and S. S. picture wholly different types, yet their quantitative ratings are very similar and help to demonstrate that the interrelation of different combinations may have very similar results. D. C., a seven year old girl of Americanized-Lithuanian parentage, was brought to the attention of the Court by a complaint charging the parents with being cruelly neglectful. The child had been found wandering on the street at night. Investigation showed that she was a case of conduct disorder—untruthful, stubborn, superficial in her emotions, easily distracted. She stole money from the family, ran away to the movies at night and recently had developed sleep-walking. While at present she functions intellectually as a Normal child and easily maintains her school grade, she does lack stability. Faulty attention and poor retentivity as evidenced in her superficiality may be the explanation of the short Reverse Span; on the other hand, her motivational defect may be the disturbing element.

Case S. S. was a dependent seven year old Jewish boy having no conduct disorder. He presented no specific defect or deficiency, though the quality of his performances was persistently mediocre and his response time was slow. While at present this boy functions adequately, he is probably using all his innate capacity to maintain a Normal, dull level. Later on, if any competency fails to function in accordance with the increased complexity demanded, it is probable that adequate compensation can not be made by the other mediocre competencies, sufficient for him to maintain a Normal standard. Each competency will barely function adequately and there will be no surplus for compensation. He will then fall back to the deficient class.

S. A. represents such seven and eight year old Subnormals as do reverse three digits. He was an Italian boy of eight years and ten months brought to the Court by his father for placement. The mother had recently died and the father felt that the children were being neglected at the boarding house. Their own home conditions had been good; his developmental history negative. The examination notes record: "Subnormal intelligence; poorly trained, super-

ficial. High distractibility of attention. Shows mediocre trainability along manual lines, but has little persistence in the face of obstacles. Educationally retarded. (I. Q. 79)." Would not his high distractibility and lack of persistence explain his subnormality, even though at his attending moments he could reverse three digits?

In Chart 2-A, the mode for the Forward Span of Normal children of nine, ten and eleven years is six digits; 49 per cent fall at the mode, 11 per cent are above and 40 per cent are below the mode. The mode of the Subnormal group of the same age is established by 49 per cent of the cases giving a Forward Span of five digits; 21 per cent of the Subnormal group give above five digits, and 30 per cent fall below the mode. It is evident, therefore, that a Forward Memory Span of five or six digits has not much diagnostic value in differentiating between the Normal and Subnormal children of nine, ten and eleven years of age, since in each group the bi-modal distribution tends to be mutually overlapping. However, no Normal child gave as short a span as four digits, though 30 per cent of the Subnormals did. This is of diagnostic significance. On the other hand, one Subnormal boy had a Forward Span of seven digits, with a reverse span of four.

This boy (P. T.) was an American, eleven years eight months old, who fulfilled the requirements in both the Forward and Reverse Memory Span for the Normal boy of his age, yet undoubtedly was of subnormal mentality. His school record was poor in conduct and in work, and his general behavior presents decided psychoneurotic traits. He is hyper-suggestible, and lacking in sustained effort. Emotionally he is shallow, responding all out of proportion to the stimulus. He has little conception of ethical values. This boy has the necessary sensitivity and impressionability, but does not have stability or retained modifiability adequate to function normally. Evidently he has sufficient retentivity to reverse four digits, but even here there may be compensation by intensity of image arising from hyper-imageability.

In Chart 2-B we have the mode for the Reverse Span of Normal children of nine, ten and eleven years of age as four digits; 20 per cent of the group have a Reverse Span of five digits and 16 per cent reverse only three digits. In contrast to the 84 per cent of Normal children who reverse four or five digits, there were 90 per cent of Subnormal children who could not give above three digits reversed. With this method the norms are definitely established and a very clear discrimination made between the groups. Of the 27 per cent of Subnormals who failed to give even three digits backward, half of them had Forward Memory Spans of only four. They belong to

the lower level of the Subnormal group and are seriously defective. The others had Forward Spans of five. The 16 per cent of Normals reversing only three digits maintained at least their group mode in the Forward Span. These groups are analogous. They represent individuals who fall below the mode of their group in the Reverse Span, yet in the final diagnosis are retained within the group. All of them belong to the chronologically younger half of the group. They may therefore represent either slight retardation or the lower limits of their respective group. In these cases, also, the Reverse Span may have real prognostic value. It is probable that the inadequate Reverse Span is an early indication that the individual is falling appreciably below his group, or that his mental competencies will early reach their maximum development.

A. H. represents a relatively small class of Normal children whose Forward and Reverse Spans are of the same length. He is an American boy of nine years seven months, in the second grade at school, but capable of doing at least third grade work. (Retardation due to prolonged absence for hospital care.) His range of general information was good; his Form Board performances were slow but the quality was good; his general reaction time throughout was slow and he showed definite effort to "gather the threads together". He very clearly presented a picture of restricted distribution of attention which necessitated a loss in reaction time, but he had adequate competency to use and to interpret the stimuli once he had assembled them. He is deficient (quantitative) rather than defective (qualitative).

E. N., age fourteen years, also gives a Reverse Span equal to the Forward. She is of subnormal mentality but shows a special aptitude for doing routine tasks with concrete material. While wasteful of her energy, she is persistent and quite readily becomes efficient in the particular task at hand. Her initial performances are poor—purely trial and error method, but she seems to retain the benefit gained through experience. She learns by doing. Physically she is fairly well developed and though, as a child, she had chorea, at present there are no positive neurological symptoms. E. N. will probably soon leave school for mill work, for which she is better fitted, and if environmental factors remain fairly constant, making few demands on her faulty judgment, she may maintain a standard of social adequacy.

In the Forward Span of the adolescent group (Chart 3, A and B) the spread of the Subnormal group parallels that of the Normal lowered by one digit: 87 per cent of the Normal children have a Forward Span of six or seven; 97 per cent of the Subnormals

have a Forward Span of five or six. A Forward Span of six has comparatively little diagnostic value with adolescent boys and girls, as 45 per cent of the Normals and 43 per cent of the Subnormals give the same response—*i. e.*, a Forward Span of six. Of the Normal adolescent children, 11 per cent give five as a Forward Span. They represent the lower portion of the group, as do the 6 per cent of Subnormals repeating but four digits. The 7 per cent of Subnormals presenting seven as a Forward Span had Reverse Spans of but three or four digits. They are exaggerated cases of the same type of children as those described in the discussion of Chart 1—*i. e.*, having excessive distribution of attention in proportion to their deficient retentivity and imageability.

In the Reverse Span the distribution is as would be expected. The mode for the Normals is well established at five digits. The mode for the Subnormals is about equally divided between three and four digits. However, there are 23 per cent Normal adolescent cases reversing only four digits, and 8 per cent of Subnormal ones reversing five digits. The former all belong chronologically to the younger half of the group, while the latter belong to the older half.

The Normal adolescent with the short Reverse Span also has his counterpart in the younger groups. The deficiency registered in the short span is either not very serious quantitatively or the compensation made by the other factors is all but adequate to overcome the deficiency. If this were not the case, *i. e.*, if the deficiency was more extensive or if there was but a slight compensation, the individual could not function well enough to be diagnosed as Normal. He would be a Subnormal with a Forward Span adequate for Normality.

Let us consider several cases in this connection. Case T. M. was a Normal boy of thirteen years, whose parents had recently died. He was in the sixth grade in school and by diligence and effort maintained a good passing mark. His Forward Span was six, Reverse Span four. With the Form Boards his initial performances were of good quality. He showed considerable trainability and avoided repeating the same errors. In the vocabulary test, he defined well those words denoting an object or specific performance, but failed to define the abstract words. He explained the former in vivid terms of his own performance, but concepts of abstraction were beyond him. As long as the task at hand involved material present to his vision and touch, his attention was held, but otherwise not. He seemed to sense that with the present impinging stimulation was stronger than his ability to retain, for he said, "I want to do things I can feel and see. I can't pretend I see them now."

The Subnormal adolescent boys and girls who repeated seven digits forward and who could reverse only three or four digits form a very interesting group. Taken as a whole, the quality of their performances, and indeed their everyday behavior, is widely scattered. Their distribution of attention is sweepingly wide and they acquire enough information to appear to good advantage. Their knowledge is superficial, their judgment faulty and they seldom sense or realize casual relations. They are typical Morons—verbalistic, superficial, veneered. As adults they are socially irresponsible and lack a qualitative stability, failing to choose the expedient alternative for perhaps a temporarily more pleasurable adjustment. Sometimes children of even greater mental defect also have long Forward memory spans. With them it seems to be a kind of echolalia persisting from childhood. It appears to be due to excessive imitativeness and associability, rather than to intensity of stimulation or clearness of image. Perhaps it is analogous to James' "impartial redintergration" immediately recalled. In these cases the value of the Reverse Span may indeed be appreciated, and by considering both the Forward and Reverse Spans, a more adequate estimate and accurate diagnosis are possible.

It may readily be maintained that in the results of every test is expressed an index of the proficiency of the co-functioning of the competencies involved, and hence this claim can bear no particular value for the Memory Span. Every performance, every act is the resultant of its functioning components, but the Memory Span as a test is remarkably free from those qualities which restrict the response of other tests of a specialized field. In the Memory Span, there is no specialized competency particularly stressed as in the experiments with color intensity. At times, it is maintained that certain clinical tests overrate training and educational attainments and are therefore comparable only in cases of equal opportunity. In the so-called Performance Tests, a simple numerical evaluation is not a true index of the child's proficiency, because the time element fails to express the quality factor which is often the most valuable contribution of the test. The Audito-digit Memory Span shares none of these peculiarities and stands pre-eminent in the accuracy of its scoring. A Memory Span is either five or not five and the response remains constant to a remarkable degree for the individual at that level of development. Furthermore, in its adequately functioning complexus, are found the major competencies upon which the social proficiency of the individual depends. As a minimum, attention, comprehension, imageability, associability and retentivity have been suggested. Trainability is not specifically represented, but its components are

there. Failing to have an adequate Memory Span indicates a deficiency, uncompensated, but it requires further observation to determine in which competency the deficiency lies. It may be in any one or more of them and would thereby equally disturb the co-functioning equilibrium of the whole.

To summarize the discussion of individual variations from group norms, we have five types of cases: the Normal Child with either the Forward or Reverse Span deficient, the Subnormal child with a deficient Forward or Reverse Span, and the child recognized as Subnormal but who conforms to the "normal mode" in both the Forward and Reverse Spans. In this study there were no Normal children deficient in both the Forward and Reverse Spans. Table III summarizes the possible explanations of such deviations, considered from the point of view herein maintained, that the ratio existing between the Forward, Rhythmic and Reverse Memory Spans expresses the index of proficiency at which the child functions mentally.

TABLE III.

Diagnosis.	*Forward Span.*	*Reverse Span.*	*Explanation.*
Normal	Adequate	Inadequate	1. Recently attained chronologically the lower age limit of the group.
			2. Mental equipment barely qualifies for Normality.
Subnormal	Adequate	Inadequate	3. Specific defect of a particular competency especially needed in Reverse Span and functioning to a lesser degree in Forward (viz., comprehension or retentivity defective resulting in lowering of general proficiency of complexus, without adequate compensation).
			4. Good distribution of attention which compensates in part (in Forward Span) for specific deficiency.
			5. Echolalia.
Normal	Inadequate	Adequate	6. Somewhat restricted distribution of attention.
Subnormal	Inadequate	Adequate	7. Considerably restricted distribution of attention.
Subnormal	Adequate	Adequate	8. Psychopathic tendencies which inhibit normal functioning of mentality during every day life.

Assembling the findings of this study in regard to the diagnostic value of the Audito-digit Memory Span with children of school age, we find that:

1st. In both the Forward and Reverse Spans, the length is dependent upon both age and mental development. In every instance the length of the span varies directly as the *ratio* between the age and mental development.

2d. The Audito-digit Memory Span indicates the *ratio* of proficiency in the co-functioning of the competencies involved. This is evidenced by—

(A) The definitely established norms characteristic of each age and group, for each method of presentation.

(B) The universal X and X + 1 relation between the Forward and Rhythmic spans.

(C) The X and X − 1 or X − 2 relation between the length of the Forward and Reverse Spans in the Normal cases, when X equals the mode for the Forward Span of that age.

(D) The failure of the Subnormal group to maintain this relationship.

(E) The adequate explanation thereby afforded of the apparent exceptions.

3d. No single method of presentation of the Memory Span Test gives adequate opportunity for the observation of the co-functioning of the component factors. At least both the Forward and Reverse methods are necessary.

4th. Considered alone, the Reverse Span has higher diagnostic value than the Forward Span, as shown by its uni-modal distribution of results and the mutual exclusiveness of the groups formed thereby.

Conclusion.

The Audito-digit Memory Span of children is of specific diagnostic value. Definite norms are established, by individual tests, characteristic of age and competency levels. The span expresses the index of proficiency of the co-functioning of all the mental competencies involved, and is not a measure of a single mental ability. Since the co-functioning of this particular complexus is most essential to social adequacy, the diagnostic value of the audito-digit memory span is thereby augmented. In general, mental development varies directly as the ratio of the Reverse Span to the Forward Span.

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